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(54) **Optimizing channel selection in cellular telephone networks**

(57) In a cellular telephone network the selection of channels of the same frequency for re-use elsewhere in the network is optimized by a statistical method in which the geographical area covered by the network is subdivided into a large number of small sub-areas of generally equal shape and size. The strength of signals received from transmitters within the network is measured at each accessible sub-area and the source of the strongest signal for the sub-area is defined as the serving cell-site centre and the remaining signals as interferer signals. Carrier to interference (CIR) ratios are thereafter calculated and compared to a predetermined minimum acceptable level of CIR for the network. For each cell site of the network the total number of sub-areas in which signal strengths have been ascertained is aggregated and compared with the number of such sub-areas in which the actual CIR is above the minimum acceptable value, to thereby determine the probability of interference occurring in that cell with one or more signals received from other cell sites within the network if the same channel frequency is re-used. The method therefore provides a means to optimize channel selection by selecting a channel having the lowest probability of interference with signals from other cells using the same channel frequency in the network.

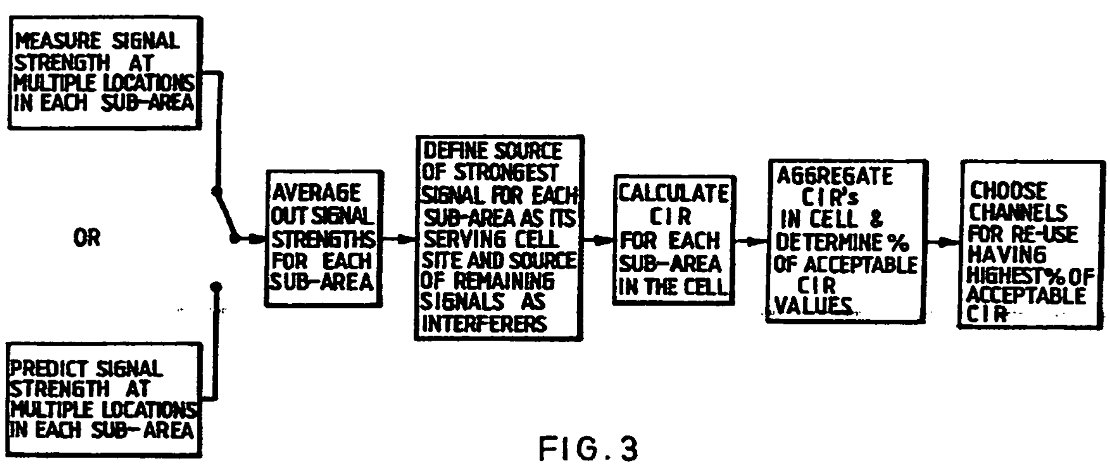

FIG. 3

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1990.

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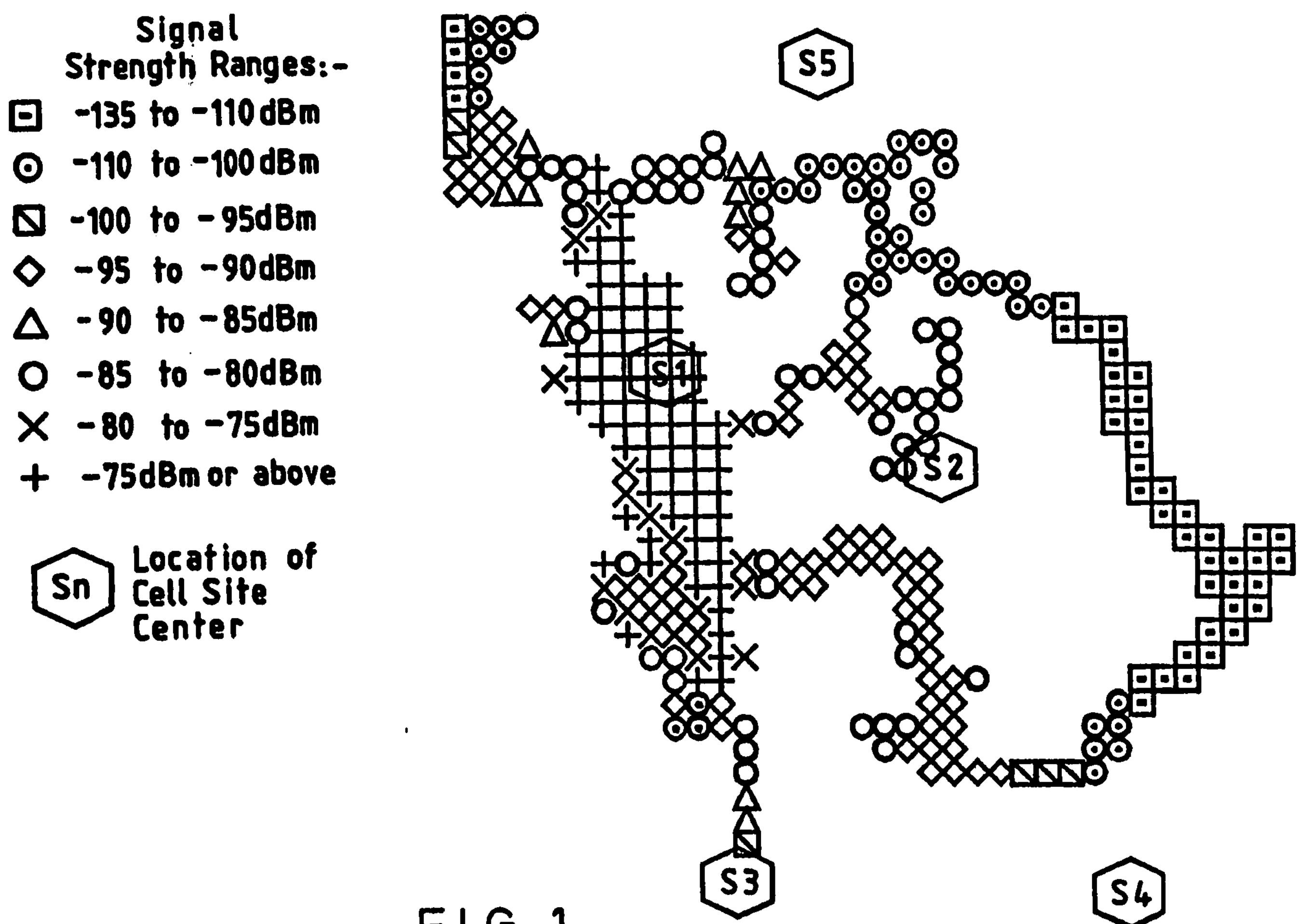

Signal
Strength Ranges:-
-135 to -110dBm
-110 to -100dBm
-100 to -95dBm
-95 to -90dBm
-90 to -85dBm
-85 to -80dBm
-80 to -75dBm
-75dBm or above
Sn
Location of
Cell Site
Center
S1
S2
S3
S4
S5

FIG.1

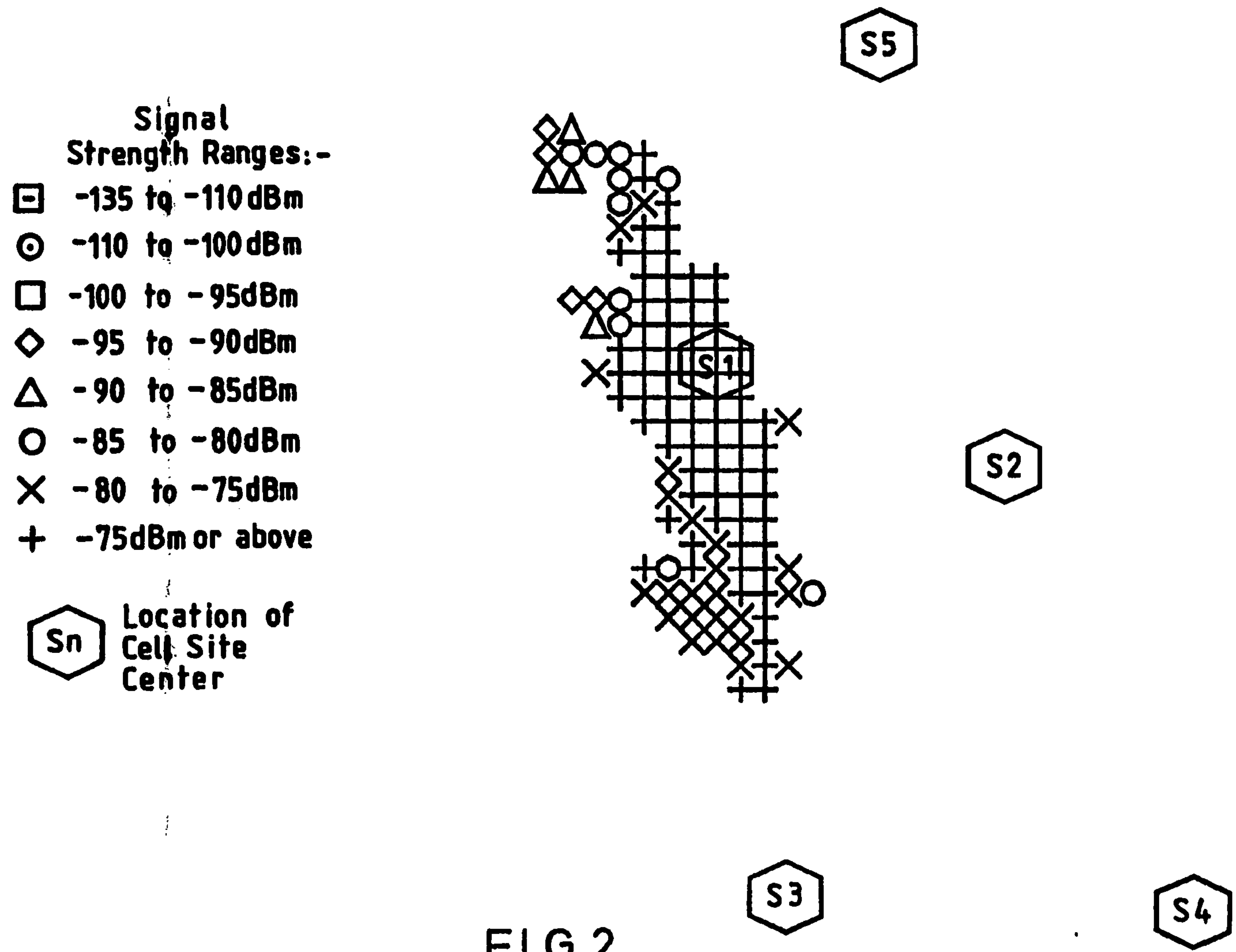

Signal
Strength Ranges:-
-135 to -110dBm
-110 to -100dBm
-100 to -95dBm
-95 to -90dBm
-90 to -85dBm
-85 to -80dBm
-80 to -75dBm
-75dBm or above
Sn
Location of
Cell Site
Center
S5
S1
S2
S3
S4

FIG.2

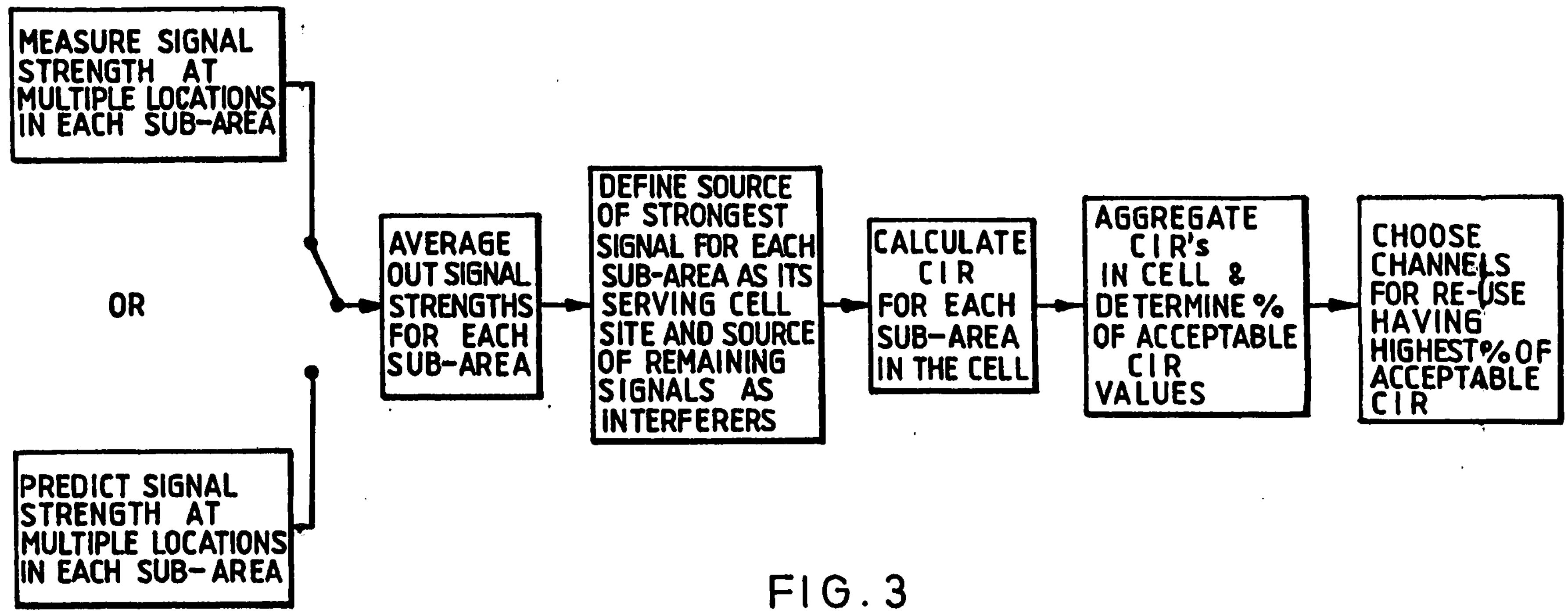
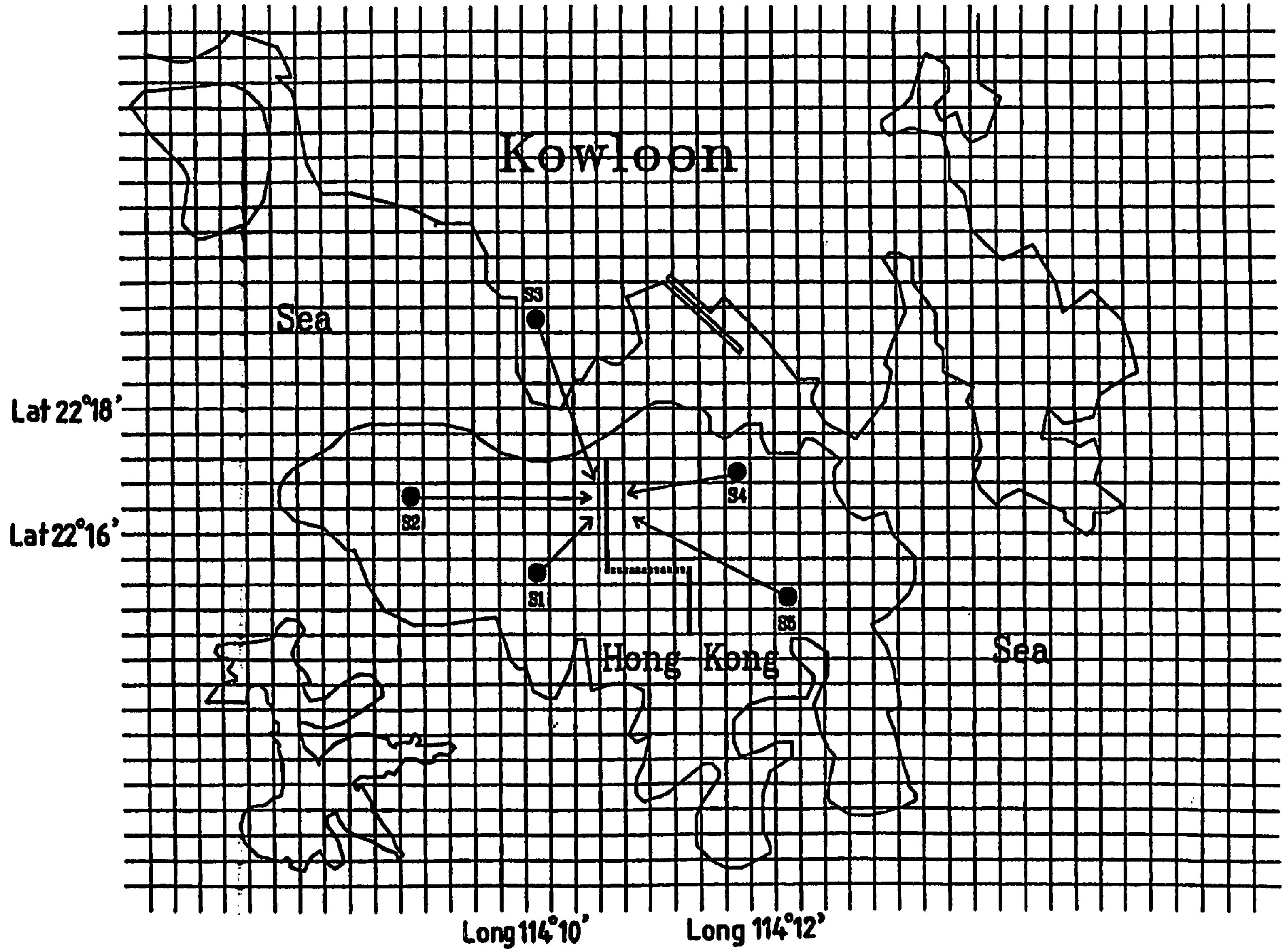

MEASURE SIGNAL STRENGTH AT MULTIPLE LOCATIONS IN EACH SUB-AREA
OR
PREDICT SIGNAL STRENGTH AT MULTIPLE LOCATIONS IN EACH SUB-AREA
AVERAGE OUT SIGNAL STRENGTHS FOR EACH SUB-AREA
DEFINE SOURCE OF STRONGEST SIGNAL FOR EACH SUB-AREA AS ITS SERVING CELL SITE AND SOURCE OF REMAINING SIGNALS AS INTERFERERS
CALCULATE CIR FOR EACH SUB-AREA IN THE CELL
AGGREGATE CIR's IN CELL & DETERMINE % OF ACCEPTABLE CIR VALUES
CHOOSE CHANNELS FOR RE-USE HAVING HIGHEST % OF ACCEPTABLE CIR

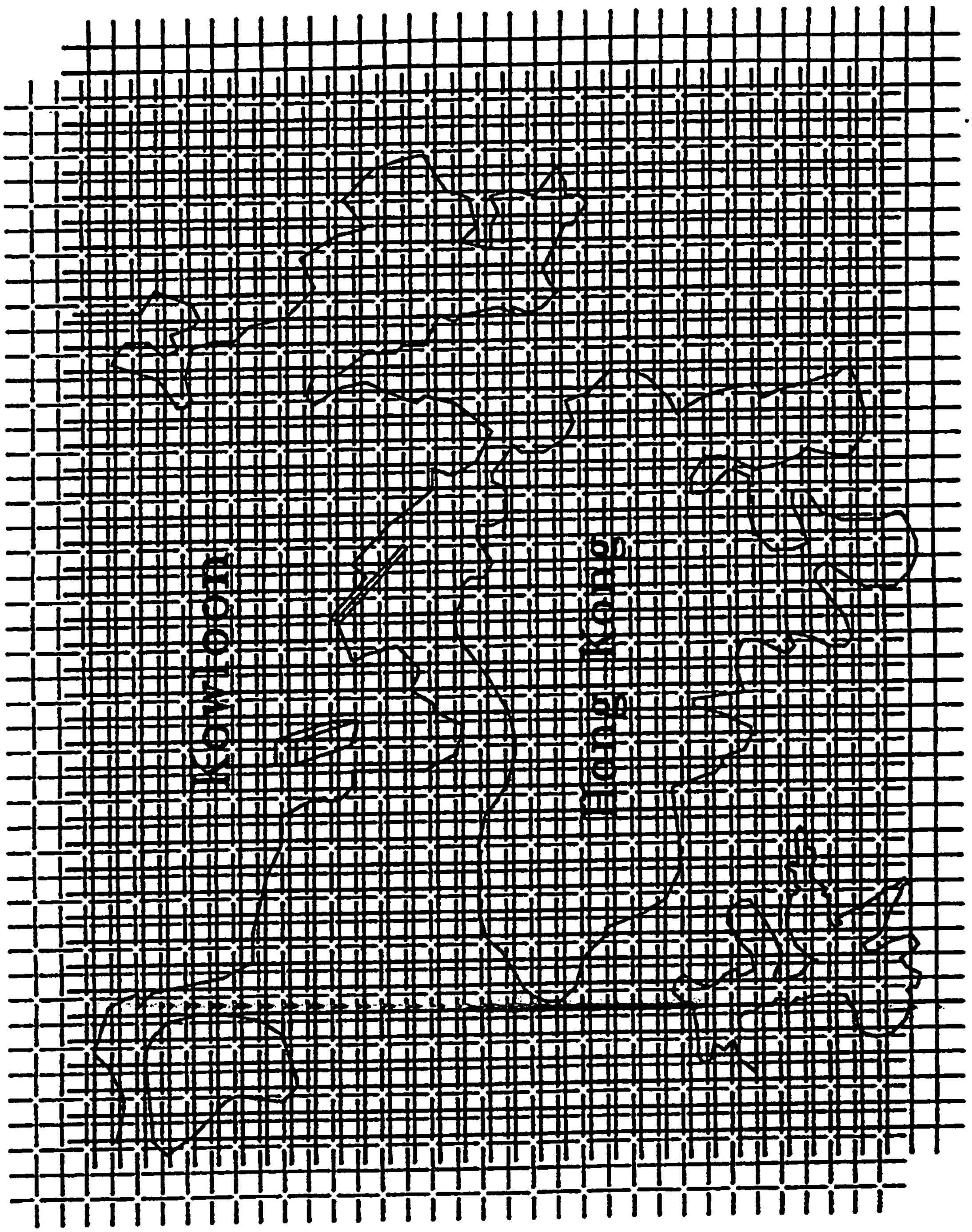
FIG. 3



Kowloon
Sea
S3
Lat 22°18'
S2
S4
Lat 22°16'
S1
S5
Hong Kong
Sea
Long 114°10'
Long 114°12'

FIG.4

FIG.5



RECORD No.	LATITUDE	LONGITUDE	S1 (	S2	S3 dBm	S4	S5)
1	22.309818N	114.169511E	-90	-115	-109	-114	-95
2	22.309901N	114.169149E	-78	-114	-93	-112	-80
3	22.310000N	114.168774E	-70	-114	-99	-101	-75
4	22.310420N	114.168778E	-75	-109	-97	-111	-78
.	.	.	.	.	.	.	.

FIG.6

Sub-area No.	LATITUDE	LONGITUDE	S1 (	S2	S3 dBm	S4	S5)
1	22.309900N	114.169000E	-78	-113	-100	-110	-82
.	.	.	.	.	.	.	.

FIG.7

Confidence	S1	S2	S3	S4	S5
S1	0%	65%	90%	70%	59%
S2	60%	0%	83%	77%	75%
S3	88%	75%	0%	70%	97%
S4	70%	80%	72%	0%	35%
S5	62%	78%	95%	30%	0%

FIG.8

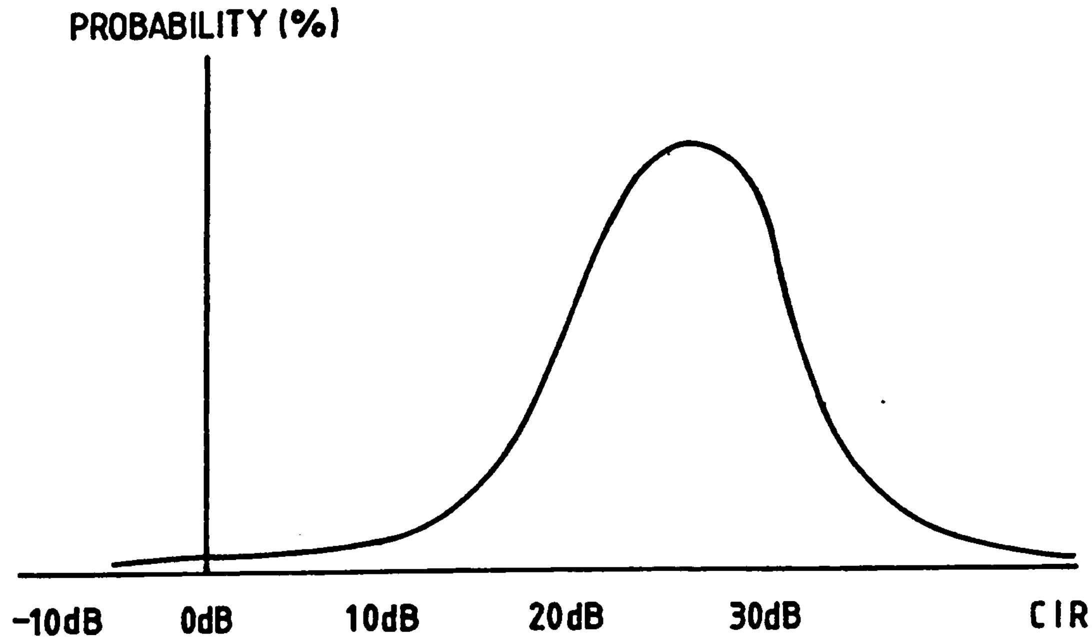

PROBABILITY (%)
-10dB
0dB
10dB
20dB
30dB
CIR

FIG.9

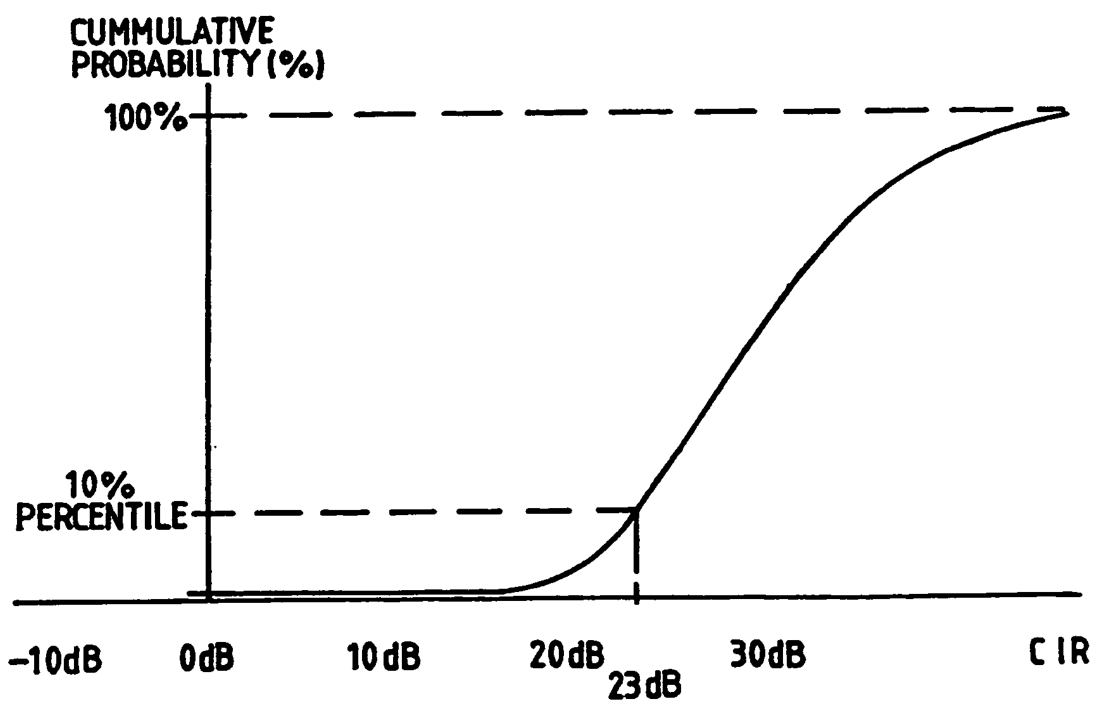

CUMMULATIVE PROBABILITY (%)
100%
10% PERCENTILE
-10dB
0dB
10dB
20dB
23dB
30dB
CIR

FIG.10

Confidence	S1	S2	S3	S4	S5
S1	0dB	12dB	29dB	19dB	10dB
S2	14dB	0dB	23dB	20dB	18dB
S3	25dB	17dB	0dB	15dB	35dB
S4	16dB	21dB	20dB	0dB	4dB
S5	10dB	19dB	38dB	2dB	0dB

FIG.11

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Method of Optimizing Channel Selection in Cellular Telephone Networks

This invention relates to cellular telephone networks and is primarily, but not exclusively, concerned with optimizing the selection of channels throughout part or all of such networks to minimize interference and maximize the performance and capacity of the network.

Cellular telephone networks stem from the realization that it is statistically improbable for a large number of subscribers to such a telephone system to be geographically close to each other at any given instant in time and/or would wish to make or receive radio telephone calls at the same time in the same location.

Given the finite number of radio channels which are available for use within radio telephone networks, the cellular network system provides a means whereby a very large number of calls can be made or received at the same time using a relatively small number of channels. To achieve this, short-range transmitters and receivers are installed

in a cell-like configuration over the entire area covered by the telephone network, each such cell having a different range of radio channels to that of a neighboring cell, but often the same as those of several other cells in the network.

Although the or each radio transmitter in each cell is relatively short-range, it will be appreciated that it would still be possible for signals of any particular channel to be picked up by receivers in nearby cells where the same channel is being reused, which can then lead to "cross-talk" interference during telephone calls. To minimize this undesirable effect it is necessary to ensure that the signal strength from a nearby cell using the same channel is sufficiently less than the signal strength for the same channel used in a particular cell so as to enable the weaker signal to be differentiated and discarded so that only the stronger signal is used during the telephone call. To achieve this aim, in the construction of cellular radio systems the concept of Carrier-to-Interference Ratio (CIR) is used, meaning, essentially, the ratio of the carrier signal strength in one cell compared

with interfering signal strength received from a nearby cell using the same channel frequency.

The CIR may also be conveniently expressed in decibels where the actual signal strength is measured in Watts. Thus, if the strength of the carrier signal in a channel is measured to be, say, $C=10x10^{-7}mW$, then C(in decibel expression) can be written to be 10 times the logarithm of the power ratio to 1 milliwatt. Hence:

$$C(dBm)=10\log \frac{10x10^{-7}mW}{1mW} \qquad (1)$$

$$C(dBm)=10\log(10x10^{-7}) \qquad (2)$$

$$C(dBm)=-60dBm \qquad (3)$$

Similarly, if the strength of the interfering channel I is, say, $5x10^{-7}mW$ then we have

$$I(dBm)-10\log \frac{5x10^{-7}mW}{1mW} \qquad (4)$$

$$I(dBm)-10\log(5x10^{-7}) \qquad (5)$$

$$I(dBm) = -63dBm \quad (6)$$

Then since:

$$CIR = 10\log\left(\frac{10x10^{-7}mW}{5x10^{-7}mW}\right) \quad (7)$$

and:

$$CIR(dB) = 10\log\left(\frac{10x10^{-7}mw}{1mW}\right) - 10\log\left(\frac{5x10^{-7}mW}{1mW}\right) \quad (8)$$

Therefore:

$$CIR(dB) = C(dBm) - I(dBm) \quad (9)$$

$$CIR(dB) = -60dBm - (-63dBm) \quad (10)$$

$$CIR(dB) = 3dB \quad (11)$$

Thus, it will be seen that if the signal strengths of the carrier and interferer are expressed in Watts then the CIR is simply ten times the

logarithm of their ratio as defined in equation (7); whereas if the signal strengths of the carrier and interferer are measured in decibel milliwatts, the CIR is obtained by calculating their difference, as shown in equation (10).

Typically, in cellular mobile radio analog systems such networks require a CIR of greater than 17 dB although it will be understood that the choice of this value is arbitrary and depends on the technology employed in the hardware used and how efficiently it is able to differentiate between signals received from identical channels but located in different cells.

In an ideal situation, the design of a cellular telephone network is relatively straightforward in that all that is required are short-range radio stations comprised of transmitters/receivers, often using common antennae, located at evenly spaced intervals over the entire geographical area required for the network, with each such station then defining the cell site centre of its respective cell. Propagation of electro magnetic radiation in such circumstances generally occurs

spherically outwards which necessarily means that if each station is positioned in the most efficient manner with respect to adjacent stations then a partially overlapping arrangement of cells results. Although the true locus of signals receivable from each station transmitter defines a circular path around its antenna, it is usually convenient to consider in an ideal situation that each cell has an hexagonal shape and when planning networks of this kind it is usually convenient to draw out the geographical spread of the network with the use of hexagonal cells, which thereby appear to interlock with adjacent cells.

In the situation referred to above it will be apparent that there is effectively only one primary consideration when planning the geographical extent of such a telephone system, being a trade-off between the cost of installing and operating stations in each cell, as opposed to the end-user requirements for making telephone calls to or from each cell. Thus, the more geographically distant a cell becomes from a centre of human population, the less cost effective it becomes to maintain and operate a cell

from that location. Hence, the planning of such an ideal network is relatively straightforward.

However, in the real world, there are many other complicating factors affecting the design of cellular telephone networks which are brought about primarily by topography and demography, or the non-availability of ideal sites where stations can be situated. Topographical factors often arise in towns and cities with high rise buildings and/or natural geological features such as hills and valleys. Demographic factors result from variations in human population densities, particularly in and around towns and cities.

The problems caused by variations in topography can generally be summed up as meaning that the ideal hexagonal shape for a cell cannot be assumed valid because there will be areas in such a cell which are blocked from receiving or transmitting radio frequency radiation as a result of the presence of buildings etc.. This problem can be solved by placing additional stations to cover the blind area within the cell, hopefully in the most economic fashion possible. Sometimes, it is even necessary to

install antennas inside buildings, particularly shopping malls and the like, where there is a high statistical probability that subscribers to the telephone network would wish to make or receive a telephone call. Alternatively, more than one attenna could be used in each cell, but located at different sector points within the cell to cover discrete sectors of the cell and thereby allow for as near complete coverage as is feasible, given the constraints dictated by the topography. Thus cells can be serviced by a single station, or split into cell-sectors, each with its own attenna, but all operating over the same bandwidth.

Demographic considerations also play their part in complicating the design of such networks because areas of high population density obviously require a greater number of available channels in order to guarantee that a caller can make and a receiver can receive a call. Given that there are only a finite number of channels usually available for allocation to a cellular telephone network, it will be apparent that efficient design of the network is necessary in order to extract the greatest amount of use possible from the available channels.

Presently, the approach taken to the design of cellular telephone networks has generally relied upon trial and error, rather than by adopting a more scientific approach, except where topographical and demographical variations are insignificant. Even in networks which have been painstakingly and carefully designed to achieve the maximum efficiency out of the number of channels available, it is still necessary to constantly review and adjust cell design within the network in response to the construction of new buildings and the demolition of old ones. Minor changes to the topography or demography can sometimes be accommodated by placing additional stations at strategic locations but, over time, the cumulative effect may make it more efficient or economical to occasionally completely redesign the network by altering the number and position of the various stations or the channels allocated to them.

Conventionally, the approach taken to optimizing the allocation of channels for re-use in neighbouring cells has been to visually analyze a radio frequency signal strength contour map for each cell, and by comparing the contour map from one cell with that of another cell, to then make a judgement,

often based upon experience, on whether or not to re-use a particular channel from a choice of several which may be available for re-use.

Obviously, if one cell receives a significant proportion of incoming radio frequency radiation from a neighbouring cell at a relatively high signal strength then it is impractical to re-use channels of the same frequency since there will be an unacceptable level of interference. Difficulties, however, arise when comparing radio frequency contour maps of cells in order to try to determine for any given cell what channels are available for re-use with the minimum possibility of interference occurring with neighbouring cells using the same channels. It may be clear from the radio frequency contour maps that certain particular channels are inappropriate for re-use, and at the other end of the scale it may be that certain other channels would be available for use since there is little or no chance of interference arising. In between these two extremes is a spectrum of possibilities and a value judgement then has to be made as to which channels to reallocate or re-use.

The present invention seeks to overcome the problem of selection of channels for re-use in neighbouring cells by introducing statistical concepts which provide a more scientific approach to the selection process. In particular, the invention effectively provides a measurement of the level of confidence for the re-use of each channel between a worst-case scenario wherein 100% interference will be experienced from a neighbouring cell using the same frequency, to a position where there is no interference whatsoever and hence 100% confidence that there will be no interference when a telephone call is made or received. Using this concept in accordance with the method of the present invention it is possible to identify confidence levels for all of the channels in the network with respect to each cell so that when a choice has to be made as to which channels to re-use in other cells the choice can be made with reference to a scale of confidence ranging from 0% up to 100%.

In accordance with the invention there is provided a method of optimizing channel selection in a radio telephone network of the type utilizing a plurality of radio stations comprised of

transmitters/receivers and antennae arranged in a cell-like configuration, the method comprising the steps of:-

(a) defining a minimum acceptable level of carrier-to-interference ratio (CIR) for the network,

(b) subdividing the geographical area covered by the network into a large number of small sub-areas of generally equal shape and size,

(c) ascertaining the strength of signals from transmitters of respective stations within the network at at least one location within all or a large number of sub-areas,

(d) for each such sub-area and for each transmitter defining the average value of the ascertained signal strength as representing the average signal strength for the transmitter in all parts of that sub-area,

(e) defining the transmission source of the strongest such signal as the serving cell-site

centre for that sub-area and the signal itself as the carrier signal,

(f) defining the remaining such signals from other transmitters within the network as interfering signals and for each calculating the CIR with respect to the carrier signal for that sub-area,

(g) for each cell-site of the network aggregating the total number of sub-areas in which signal strengths have been ascertained and comparing the number of such sub-areas in which each CIR is above the minimum acceptable value with the aggregate total of sub-areas in the cell-site, to thereby determine the probability of no interference occurring in that cell with one or more signals received from other cell-sites within the network if the same channel is re-used, and

(h) when choosing a channel for use in a cell, selecting the one having the lowest probability of interference with signals from other cells using the same channel, thereby to optimize channel selection.

It will be understood that one or more of the steps referred to above and in the appended claims may be interchanged, for example if it is found to be more convenient to ascertain at various locations the value of signals received from various transmitters first and then define sub-areas and cell-sites accordingly. The method of the invention is therefore not intended to be sequentially limited and, similarly, it will be apparent that the method can be used to optimize channels selection even in new networks or networks which are completely re-designed and where no existing cell-sites have yet been allocated.

If the signal strengths are ascertained only once at each sub-area then obviously each value is also the average value and no separate averaging step is necessary.

The signal strengths of the various channels at the various locations within the network can be ascertained either by direct measurement or by predictive means such as by using mathematical models to calculate the likely propagation of radio frequency radiation. However, in cities with a high

density of high rise buildings mathematical calculation of radio frequency propagation becomes extremely complex and in such circumstances direct measurement is preferred.

Preferably, particularly when optimizing channel selection in radio telephone networks for use in cities, the geographical area covered by the network may be subdivided into layers of sub-areas of generally equal shape and size so as to accommodate variations in radio frequency propagation caused by the presence of buildings or other geographical features. Thus, one layer may correspond to ground level and the second layer may correspond to, say, a floor above ground level and so on. In this way, vertical abnormalities of radio frequency propagation can be accounted for and adjustments made to channel selection as necessary.

Conveniently, a grid system may be used to subdivide the geographical area covered by the network (using longitude and latitude) to define the sub-areas and where more than one layer is used one grid may directly overlay another.

Preferably, the likelihood of interference occurring in any particular cell with one or more signals received from other cell sites within the network if the same channel is re-used in that cell may be expressed as a level of confidence ranging from 0%, meaning that interference will occur whenever a call is made from whatever location within the cell site, to 100%, meaning that interference will never occur at any location within the cell site. Hence, the level of confidence for re-use of a channel at any point within the entire network can be calculated and expressed in the form of a look-up table so that for any one of perhaps several hundred available channels in a network then, depending upon the geographical position identified, there will exist a variety of options on whether or not to re-use any particular channel, with some channels having a low confidence level for re-use and others having a high level of confidence, perhaps nearing 100%.

The advantage of such a system is that it does not rely upon an intuitive interpretation of radio frequency contour maps but more upon

statistical data obtained by direct measurement or calculation.

The method of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a radio contour map of a cell site within a conventional cellular telephone network,

Figure 2 is a radio coverage map of the cell site of Figure 1,

Figure 3 is a block diagram showing the principle steps involved in the method of the invention,

Figure 4 is a simplified schematic diagram showing a number of transmitters within a network and locations for which measurements of signal strength have been taken, including various sub-areas defined by grid lines over the territorial extent of the network,

Figure 5 is a further schematic diagram similar to that of Figure 4 but in which two layers of sub-areas are defined by grid lines,

Figure 6 is a table showing a list of signal strength measurements taken at various locations within a sub-area,

Figure 7 is a table showing the average of the signal strengths of Figure 6,

Figure 8 is a table showing in percentage terms the probability of interference occurring through the use of the same channel at various cell sites within the network,

Figure 9 is a probability distribution graph of a collection of CIR's between two transmitters,

Figure 10 shows the cumulative probability distribution of the graph of Figure 9, and

Figure 11 is a table corresponding to Figure 8 but expressing probability of interference in dB.

Referring firstly to Figure 1 there is shown a radio contour map of a cell site S1 located within a large city having a multitude of high-rise buildings and/or geographical features which block or hinder the typically spherical propagation of electro magnetic radiation. The map includes blank areas which typically signify the presence of buildings, or areas which are otherwise inaccessible for taking measurements of signal strength. The locations of other cell-sites S2, S3, S4 and S5 in the network are also shown.

But for the presence of buildings and assuming that the topography was completely flat the contour map would show signal strength diminishing at a rate solely depending upon the distance from the transmission source. In practice, however, a typical contour map such as the one depicted is highly irregular in shape and extent. It will be understood that the contour map of Figure 1 depicts the variation in signal strength over distance in respect

of a transmitter placed at the centre of the cell site and that for each cell site on the map a different contour would result such that if contour maps for a number of adjacent or neighbouring cell sites were overlaid one on top of the other the resulting combined contour map would be extremely complex and difficult to interpret.

In Figure 2 there is shown a radio coverage map of cell site S1 corresponding to the contour map of Figure 1 but showing only those areas having signals stronger than those receivable from adjacent cells so that the map shows those areas where the cell site S1 provides dominant signal strength to make and receive radio telephone calls. As mentioned previously, it is generally accepted that in cellular mobile radio analog systems, a signal strength difference greater than 17dB is necessary to ensure that the telephone equipment within the cell can differentiate the carrier signal from interferer signals of the same frequency emanating elsewhere.

Turning to Figure 3 there is shown a block diagram of a schematic arrangement in which the preferred method of the invention can be realized in

which it will be seen that the first step can be achieved in either of two ways, either by direct measurement of signal strength or by calculating the signal strength at various points over the entire network. Prior to this, the geographic extent of the network is subdivided into sub-areas and in the example shown with reference to Figure 4 it will be seen that a square grid system is used where each of the sub-areas is of the same size and shape. In practice, the sub-areas are in fact much smaller than those depicted in Figure 4 and may typically measure 50 metres by 50 metres so that for each cell of the network a large number of sub-areas can be defined. In general, the larger the number of sub-areas defined, the greater the statistical accuracy is of the method in accordance with the invention. The grid is preferably defined and the sub-areas individually identified using latitude and longitude.

Predictive calculation of the signal strength in each sub-area can be used with reasonable accuracy over generally flat terrain including areas of water but becomes less reliable with increasing irregularity of topography and/or distance from each station within the network. Thus, in and around

cities direct measurement of signal strength is preferred to calculation and for this purpose a specialized road-going vehicle can be used equipped with conventional instruments and tracking apparatus in order to determine at any point in time the exact geographical location of the vehicle and to take at regular intervals of, say, 10 or 20 metres, measurements of signal strengths being received from nearby transmitters, the vehicle equipment automatically recording data as it moves along for later analysis. This will generally mean that such a vehicle will have to travel along roads and other areas where vehicular access is possible throughout the entire network in order to obtain a meaningful quantity of data which can then be used to provide the basis for the statistical method of the invention. In areas where vehicular access is impossible then measurements may have to be taken individually, or mathematical methods may be used instead in order to ascertain the likely signal strength at such inaccessible parts of the network. The greater the number of sub-areas covered, the greater the statistical accuracy of the method.

Once the data is collected, by whatever means, the mean signal strength in each sub-area for each transmitter is calculated and the transmission source of the strongest such averaged signal is then defined as being the serving cell site centre for that particular sub-area and therefore the signal itself is defined as being the carrier signal. The remaining signals are thereafter defined as interferer signals so that it is then possible to simply calculate the carrier to interference ratio with respect to each of the interferers for the sub-area. Obviously, the geographical extent of the cell includes all sub-areas in which the transmission signal for that cell is the strongest, but the cell itself may extend to other areas where measurements may not have been taken.

For each sub-area in each cell the average CIR with respect to nearby transmitters is therefore known and, accordingly, will be either above or below the minimum acceptable value of CIR for the network. For all sub-areas in the cell where a CIR value is known the number of such sub-areas is then aggregated and the percentage having a CIR value above the minimum acceptable is thereafter determined, in

respect of each of the interferers, from which it will be understood that this percentage in reality reflects a level of confidence in whether or not there is likely to be interference in that cell if the same channel as is used in a neighbouring cell is re-used. Thus, when choosing which channel to re-use it is simply necessary to choose the one with the highest percentage of acceptable CIRs, rather than having to rely upon the "look and feel" of radio contour maps, which has traditionally been the method used.

Turning now again to Figure 4 it will be seen that in the simplified arrangement shown measurements have been taken, (indicated by an "X") at various points over several sub-areas and at each such point measurements have been taken corresponding, respectively, to signals received from transmitters at cell sites S1 to S5. As explained above, for each sub-area the signal strengths for each transmitter are averaged out for each sub-area and the source of the strongest signal is thereafter defined as being the cell site centre for that sub-area.

In Figure 5 the two dimensional grid network is expanded to three dimensions by introducing a second layer overlying the first. More than two layers could, of course, be used depending upon the prevalence of, particularly, high rise buildings in the network although it will be appreciated that taking measurements of signal strengths at locations on the second and any successive layers is more difficult than taking measurements of signal strengths at ground level.

Turning now to Figure 6 there is shown a table of actual measurements (expressed in dBm) taken in one particular sub-area of a network where a total of four measurements have been made for each of five transmitters in cell sites S1 to S5, such measurements being taken at various positions of latitude and longitude within the sub-area. At position 22.309818 North and 114.169511 East the signal strength of the transmitter of S1 was recorded as -90dBm, that of S2-115dBm, S3 at -109dBm and S4-114dBm, and so on.

In Figure 7 there is shown a table in which the data collected and recorded in Figure 6 has been

averaged out, including the average location and, of course, the mean signal strength for each of the transmitters from S1 to S5. In practice, most networks include a large number of transmitters at a correspondingly large number of stations and hence in reality a very large number of measurements and calculations would have to be made to cover the entire network, for which purpose computer processing of the data is almost indispensable.

As mentioned with reference to Figure 3, the averaged data for each sub-area is then collated with reference to other sub-areas in each cell so that if, say, there are 100 sub-areas in a given cell and the measurements taken indicate that in 90 of those sub-areas the CIR with respect to a neighbouring transmitter is below the acceptable value of 17dB then it follows that this can be expressed as only a 10% confidence level of there not being interference anywhere in the cell should the same channel of the neighbouring cell be re-used in that cell. Conversely, if 90 out of the 100 sub-areas measured show that the signal strength from a neighbouring transmitter is relatively low so that the CIR is above the acceptable level of 17dB then

this translates into a 90% level of confidence that if that same channel is re-used in the cell then for most of the time no interference will be experienced. Obviously, the nearer one gets to 100% then the greater the certainty that no interference will occur.

Using these concepts it is therefore possible to tabulate in percentage terms the level of confidence of re-use of channels within the network for each cell or cell-sector so that it is possible to produce a look-up table of the type as is shown in Figure 8. In the table it will be seen that percentage levels of confidence have been calculated for each transmitter with respect to other transmitters in the network and, as is to be expected, those transmitters furthest away from each other usually produce higher levels of confidence and, conversely, the nearer transmitters are to each other the lower the level of confidence. In the table, and looking initially at the transmitter of S1, it will be seen that with respect to itself and by definition there is 0% confidence of interference not occurring by the re-use of the same channel. The

same is true of the transmitter at S2 with respect to itself and so on.

Referring, for example, to cell site S3 it will be noted that there is a 97% confidence level with respect to cell site S5, meaning that if the same channel is re-used in S5, 97% of the total sub-areas covered by S3 are free of interference. Conversely, there is only 3% probability, on average, in the S3 coverage area of interference occurring as a result of cross talk. Alternatively, if the same channels are used by S3 and S5, 95% of the S5 coverage area will anticipate no interference and only 5% of the S3 area is likely to suffer from interference.

The table shown in Figure 8 is necessarily simplistic, bearing in mind that a typical cellular telephone network can have over 300 individual channels within the radio frequency bandwidth allocated to it. For a single large city, there may be as many as 100 cell sites, each being allocated a number of channels dependent upon the user requirements in each cell and, of course, including some channels which are being re-used elsewhere

within the network by other cell sites. Whilst this illustrates the complexities involved in the conventional methods of trying to optimize channel selection and cellular telephone networks, it also illustrates how the statistical method of the present invention can be used for providing a sound basis for making a choice as to which channels to reallocate elsewhere, and where they can be most efficiently allocated.

Figure 8 illustrates how the confidence level for reusing channels throughout the network can be expressed in percentage terms although it will be appreciated that other ways of expressing whether or not interference is likely could be used. The percentage method shown above shows the degree of confidence of the CIR being above the acceptable value of 17dB. An alternatively is to express the CIR value in dB if the confidence level is fixed to a predetermined acceptable percentage of, say, 90%. In Figure 9 there is shown a probability distribution of a collection of CIR data between two transmitters each located at two different cell sites in the network. In this illustrative example it will be seen that there is a low probability of the CIR being

significantly below 17dB and, conversely, there is also a low probability of the CIR being significantly above about 35dB. Most of the CIR values lie between about 20dB and 35dB.

If the probability distribution shown in Figure 9 is expressed cumulatively, then we have the graph shown in Figure 10 in which, again, only a small percentage of the sample contains a CIR of less than 17dB. In the graph the 10% percentile represents a 90% confidence level and gives a CIR reading of 23dB. Accordingly, the confidence level of 80%, 70% and 60% are, respectively, represented by 20%, 30% and 40% percentiles respectively. The larger the CIR value, the higher is the confidence level. By applying the percentile method and again using 10% as the chosen percentile, Figure 8 can therefore be expressed in a different manner, as is shown in Figure 11. In the table it will be seen that as with the percentage levels of confidence shown in Figure 8, we now have confidence expressed in decibels and, as is to be expected, those transmitters furthest away from each other usually produce a higher level of dB then those which are relatively near to each other, although this is not

always the case due to variations in radio propagation cause by the presence of buildings, or areas of water which tend to increase the distance over which the radio frequency being can propagate without serious degradation. Looking initially at the transmitter of S1 it will be seen that with respect to itself and by definition the CIR is 0dB. Conversely, with respect to S1 the CIR is 29dB meaning that if the same channel is used in both of these cell sites then there is little risk of interference occurring.

Claims

1. A method of optimizing channel selection in a radio telephone network of the type utilizing a plurality of radio stations comprised of transmitters/receivers and antennae arranged in a cell-like configuration, the method comprising the steps of:-

(a) defining a minimum acceptable level of carrier-to-interference ratio (CIR) for the network,

(b) subdividing the geographical area covered by the network into a large number of small sub-areas of generally equal shape and size,

(c) ascertaining the strength of signals received from respective stations within the network at at least one location within all or a large number of sub-areas,

(d) for each such sub-area and for each transmitter defining the average value of the ascertained signal strength as representing the average

signal strength for the transmitter in all parts of that sub-area,

(e) defining the transmission source of the strongest such signal as the serving cell-site centre for that sub-area and the signal itself as the carrier signal,

(f) defining the remaining such signals from other transmitters within the network as interfering signals and for each calculating the CIR with respect to the carrier signal for that sub-area,

(g) for each cell-site of the network aggregating the total number of sub-areas in which signal strength have been ascertained and comparing the number of such sub-areas in which each CIR is above the minimum acceptable value with the aggregate total of sub-areas in the cell-site, to thereby determine the probability of no interference occurring that cell with one or more signals received from other cell-sites within the network if the same channel is re-used, and

(h) when choosing a channel for use in a cell, selecting the one having the lowest probability of interference with signals from other cells using the same channel, thereby to optimize channel selection.

2. The method according to Claim 1 further characterized in that the sub-areas are defined by a grid system using longitude and latitude to identify each such sub-area.

3. The method according to Claim 1 or Claim 2 in which layers of sub-areas of generally equal shape and size, but vertically separated, are provided.

4. The method according to any one of the preceding claims further characterized in that the probability of interference occurring in a cell in which the same channel is being used elsewhere within the network is expressed as a level of confidence.

5. The method according to Claim 5 in which the confidence is expressed in the form of a look-up table.

6. The method according to Claim 4 or Claim 5 in which the confidence is expressed as a percentage, 0% corresponding to a high probability that interference will be experienced and 100% corresponding to a very low or zero probability that interference will be experienced.

7. The method substantially as hereinbefore described with reference to and as shown in Figure 3.

8. The method according to Claim 4 or Claim 5 in which the confidence is expressed as a CIR value above or below the minimum acceptable CIR for the network.

9. The method according to Claim 8 in which the confidence is expressed in dBs.

10. The method substantially as hereinbefore described with reference to and as shown in Figure 11.

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Examiner's report to the Comptroller under Section.17 (The Search Report)

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Databases (see over)

(i) UK Patent Office

(ii)

Search Examiner

S J DAVIES

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30 OCTOBER 1992

Documents considered relevant following a search in respect of claims 1-10

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
A	GB 2234142 A (NEC) see eg page 2 line 11 - page 3 line 5	

SF2(p) HCS - doc99\fil000540

Category	Identity of document and relevant passages	Relevant to claim(s)

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